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XVII.—*Notes on Fossil Calcispongiæ, with Descriptions of new Species.* By GEORGE JENNINGS HINDE, Ph.D., F.G.S.

[Plates X., XI., & XII.]

IN the course of a recent examination of the fossil sponges in the British (Natural-History) Museum at South Kensington, I devoted particular attention to those forms which have been grouped together by Prof. Zittel as a new family of calcareous sponges under the term "Pharetrones," with the view of discovering, if possible, some fresh evidence which would serve to determine the validity or otherwise of this classification, which has been contested, more particularly in this country, by two eminent authorities on recent and fossil sponges—Messrs. Carter and Sollas. To my good fortune, I succeeded beyond my anticipations in ascertaining some fresh facts respecting the spicular structure of several sponges of this family, which appear in my estimation to be of importance in deciding the question of their true character; and my purpose in this communication is to describe these new facts and discuss their bearing on the subject.

The family of the Pharetrones, described by Zittel in his 'Studien über fossile Spongien' (of which a translation by Mr. W. S. Dallas, F.L.S., is contained in the third and fourth volumes of the 'Annals' for 1879), embraces a very numerous group of fossil sponges which occur in strata from the Devonian to the Cretaceous inclusive. In regard to outer form, these sponges possess the same variety which is met with in fossil siliceous sponges; but as a rule they are individually of much smaller dimensions. Their main characteristic feature is the possession of a fibrous skeleton, composed of carbonate of lime, and, unlike many other fossil sponges sometimes associated with them in the same strata, whose skeletons are also calcareous, this material forms the original skeleton, and is not the result of subsequent replacement. The fact, now generally recognized by those who have studied fossil sponges, that the present calcareous or siliceous condition of these bodies affords of itself no certain indications of their original composition, has caused a great amount of confusion. It is only within a comparatively recent period that the instability of the organic silica in sponge-spicules and its replacement by calcite in many fossil sponges has been demonstrated. Before this fact became known all fossil sponges with calcareous skeletons were regarded as possessing this mineral constitution originally; for calcite was generally thought to be much less stable than silica, and it was believed impossible that it could replace this latter material. At the present time, with many authorities, the belief is in the opposite direction, and, instead of regarding all sponges with calcareous skeletons as formed originally of this material, it is asserted that no known fossil sponges were originally calcareous, and that all those with calcareous skeletons have become so by dissolution and removal of the original silica and its replacement by calcite. It becomes therefore a matter for the exercise of judgment to determine the original composition of any fossil sponge. In the case of sponges, for example, whose skeletons are built up of lithistid or hexactinellid spicules we are enabled at once to determine that their composition, though now frequently calcareous, was originally siliceous; for we know that in all existing sponges with this type of spicular structure the composition is invariably siliceous; and, further, the fossil examples occur frequently both in a calcareous and siliceous condition, and those which are siliceous exhibit the outer form and interior canal-structure of the component spicules in a comparatively perfect state, whilst the opposite occurs with those which are calcareous; and from this we may conclude that this latter material is not the original constituent of the skeleton of these sponges.

The fibrous character of the skeleton of the Pharetrones, however, is so unlike that of any existing calcareous sponge that we are unable to apply the comparison which enables us to determine its original composition, as in the case of the siliceous sponges just mentioned. In all existing Calcisponges the spicules forming the skeleton are imbedded in the exoderm or syncytium of the sponge, and never form, as in the case of the Pharetrones, anastomosing solid fibres. Thus loosely imbedded in the sarcodic material of the syncytium, it would be impossible that they should be able to retain their arrangement after the death of the animal and the consequent destruction and decay of the syncytium. This perhaps led Häckel to state in his magnificent monograph that up to the present (1872) not a single fossil calcisponge is known (vol. i. p. 241). He further adds, "One might expect to find the microscopic calcareous spicules of these sponges as fossils in different strata; and probably with more complete micro-geological investigations these will be abundantly found; but up to the present none have ever been described and figured."

If, however, it can be shown that the skeleton of the fossil Pharetrones, though disposed in the form of solid anastomosing fibres, is yet built up of calcareous spicules which show the closest agreement in form with those of existing calcisponges, the objection raised against their alliance with the existent examples of the order would be deprived of most of its importance; for it is on the character of the individual spicules of the skeleton rather than on their arrangement that the classification of both siliceous and calcareous sponges, recent as well as fossil, depends. The following observations of Häckel with respect to the spicules of the existing Calcispongiæ will equally apply to the fossil examples of the order. He says that, notwithstanding there is much less variety in their form, arrangement, and combination than in those of siliceous sponges, yet they are of the highest morphological value, and afford the only sure foundation for a natural classification and a genealogical system of the calcareous sponges.

In studying the characters of the fossil Calcisponges we encounter a difficulty arising from the frequent obliteration of all traces of spicules in the fibres through the changes which have taken place in the process of fossilization. In many instances the fibres only show a structure of finely radiate calcitic crystals; in others but faint traces of spicules here and there can be detected; and even where the spicular structure is fairly preserved the only method available for examination is by means of thin microscopic sections, which, except in the cases of the simplest forms of spicules, and then only when the plane of the section corresponds with that of the spicule, do not allow a satisfactory investigation of the entire spicule. When only thus partially seen, some of these calcareous spicules have been, by some authorities, compared to the spicules of siliceous monactinellid and tetractinellid sponges whose original constitution is now replaced by calcite. Hitherto the spicules of fossil calcisponges have never been noticed in the free state, and our knowledge of the minute structure of the Pharetrones has been solely derived from the study of thin microscopic sections.

Leaving aside for the present the consideration of the true characters and affinities of the spicules of the Pharetrones, it is worth while to inquire if the character of the strata in which these fossils occur, and the condition of other fossils associated with them, will give any subsidiary help towards solving the question of their original structure. As nearly all the Pharetrones which are met with in this country are derived from the Lower Greensand, the Upper Greensand, and the Upper Chalk, we need not in making our inquiries go beyond these three horizons. Beginning with the lowest, it is somewhat remarkable that a very large proportion of the Pharetrones in England has been yielded by the Lower-Greensand strata of Faringdon, in Berkshire. So abundant are these organisms that the bed containing them is known as the "Sponge-gravel." It is a conglomerate of siliceous sand and gravel, hardened by a ferruginous cement. The sponges form a large part of the bed; the material surrounding and enveloping them, if we except the remains of other organisms, is entirely siliceous, while the sponges themselves are entirely calcareous and are acknowledged to have grown in the same beds in which they are now found. It is therefore altogether improbable that the sponges in this gravel-bed should have had their skeletons, if originally siliceous, so completely replaced by calcite, a material which is now not present in these beds save in the remains of these and other calcareous organisms. On the other hand, the unaltered appearance of these sponges and the resemblance of the calcite of their skeletons to that of the shells and other organisms associated with them favour strongly the opinion that they still possess their original calcitic structure. No undoubted siliceous sponges have, so far as I am aware, been discovered with the Pharetrones in this sponge-gravel. Prof. Sollas admits the difficulty of explaining, on his hypothesis of the original siliceous composition of these sponges, their present calcareous condition in this bed, on account of not finding the silica resulting from the solution of their original structure; but he supposes that it has been carried away by current-action of the seas and subsequent drainage of percolating waters *. He makes no reference to what appears to

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* Ann. & Mag. Nat. Hist. 1878, vol. ii. p. 362.

me the far greater difficulty of accounting for the complete substitution of silica by calcite in a stratum where free calcareous material does not exist.

Passing now to the Upper Greensand, Pharetrones occur, though not very abundantly, in beds of this age at Warminster; and in the same locality and in beds of similar lithological characters there are numerous examples of siliceous lithistid sponges. The comparison of examples of these different groups thus preserved under similar conditions is very instructive, and shows, one may say almost at a glance, such great differences, that no one could suppose that both these groups were originally siliceous in composition. The matrix is of quartzitic and green grains, hardened by a siliceous cement, without any trace of calcareous material. The Pharetrones in this Warminster Greensand are entirely calcareous; their outer form is perfectly preserved; and the fibre, both at the surface and in the interior of the sponge, is alike of a comparatively soft white earthy material, whilst the interspaces are filled by the transparent quartzitic and green grains of the matrix. Altogether different are the appearances presented by the siliceous lithistid sponges in these same beds. The sponges themselves are siliceous; the outer form is preserved; but the exterior surface in the majority of the specimens exhibits only the cemented grains of the matrix, with here and there partially obliterated spicular structure. In the interior the spicular skeleton is either imbedded in glassy silica, or it not unusually happens that the siliceous spicules have been dissolved and their empty moulds remain. In no single instance have I found these moulds refilled with calcite. On the hypothesis of the siliceous origin of the Pharetrones it appears inexplicable that they should now be exclusively and completely calcareous, whilst the undoubtedly siliceous Lithistids should yet retain their siliceous structure. The present differences can only be understood by admitting the calcareous origin of the Pharetrones.

It is, however, on the Pharetrones in the Cambridge Greensand, and more particularly on the structure of *Pharetrospongia Strahani*, Sollas, that Prof. Sollas bases his arguments in favour of the siliceous character of these fibrous sponges. The matrix enclosing the sponges is a dark bituminous material; the brown and greenish grains of which it is composed appear to be cemented, in part at least, by calcite; for after treatment with acid they are disintegrated. The sponge-fibres are mainly composed of calcite which readily dissolves in acid; but very frequently there remains here and there a thin delicate film, forming, as it were, a sheathing on the exterior surface of the fibre, chiefly consisting of the minute spicules, now siliceous and cemented together by siliceous material. Now at first sight it might be said that in this sponge at least the original structure was siliceous; for some, though only a very small portion, of the fibre yet retains a siliceous composition. A comparison, however, with the present condition of siliceous hexactinellid sponges occurring in the same beds throws great doubt on such a conclusion. So far as my experience extends, none of the hexactinellid sponges in this Cambridge Greensand retain their original siliceous structure; their spicular skeletons for the most part are now represented by hollow moulds: and on the hypothesis of the siliceous origin of *Pharetrospongia*, one would have expected to find the fibres dissolved away in a similar manner, and the empty moulds remaining; but this condition never occurs. It is true that occasionally the moulds of the hexactinellid spicules have been infiltrated with calcite; but this replaced material is of quite different character from that of the fibre of *Pharetrospongia*. There is another fact which tends to prove that the siliceous spicular film occasionally present in the fibres of *Pharetrospongia* is of secondary origin, which is that it is invariably restricted to the *exterior* of the fibre, whilst the interior remains calcareous. If the fibre had been originally siliceous throughout, it would naturally have been expected that the *interior* portions, those least exposed to the influences of change, would have retained the original structure the longest, whereas the interior is invariably calcareous. On the hypothesis of the original siliceous structure, it seems to me inexplicable that the fibre should have remained siliceous on the exterior, and that the interior should have been replaced by calcite. If, however, we suppose the original constitution of the fibre to have been calcareous, and a subsequent silicification of the exterior surface to have taken place, the explanation is at once simple and easy to be understood. This explanation receives confirmation from the phenomena presented by examples of this same sponge (*Pharetrospongia Strahani*) which are abundantly met with in the Upper Chalk of Kent and Sussex. In these specimens the fibre is smooth, white, and purely calcareous in its composition. The form and outline are perfectly preserved, in striking contrast to the condition of the siliceous hexactinellids in the same strata, of which the originally siliceous spicular mesh has been completely dissolved away, leaving either hollow moulds or a secondary replacement of a loose powdery oxide of iron. Some specimens, however, of the calcareous *Pharetrospongia* have been enveloped by flints; and I have discovered that these examples have suffered a similar change to that which has happened with the Cambridge-Greensand specimens; namely, the interior portion of the fibre remains calcareous and can be removed by acid, whilst the exterior, in immediate contact with the flinty matrix, has become silicified. This fact very clearly shows the secondary origin of the siliceous envelope of the fibres of *Pharetrospongia.*

It seems to me therefore that the originally calcareous structure of the Pharetrones is strongly supported by the present condition of these fossils and the contrast between them and the remains of siliceous hexactinellid and lithistid sponges which are present in the Lower and Upper Greensand and the Chalk.

The new facts which I have to bring forward respecting the spicular structure of the Pharetrones mainly rest upon the discovery that, in certain sponges of this group from the Upper Greensand of Warminster, the fibre is in such a loose semi-friable condition that the spicules composing it may be obtained, in some instances quite, in others partially, free from the matrix, thus enabling their true forms and proportions to be ascertained with a degree of accuracy which it has been impossible to arrive at by a study of thin microscopic sections. These Warminster sponges not only presented this peculiarity of the fibre, but they also exhibited on the outer or dermal surface a layer of spicules differing in form and size from those composing the inner fibre, and sufficiently large in some instances to be visible with a strong simple lens. This discovery led me to make a special search for these surface-spicules, and resulted in proving their occurrence on the exterior of several different genera of Pharetrones both from Cretaceous and Jurassic strata. The significance of this discovery will be understood from the fact that in their character and position these surface-spicules, as will be hereafter shown, strikingly resemble those of existing Calcisponges.

The Warminster sponges above referred to belong to two genera (*Verticillites*, Def., and *Corynella*, Zittel); but they appear to me to constitute new species. In common with the other calcareous sponges from these beds, these retain their outer form well preserved and mostly free from the matrix, which consists of a somewhat coarse-grained quartzitic sand with green particles, probably of glauconite. The fibres of the skeleton have a dull white aspect, alike in the interior and on the exterior surface; and, as already mentioned, they are in places partially disintegrated, and break up into a soft powdery material, in which many of the spicules remain, though for the most part fragmentary. Subjoined are detailed descriptions of the Warminster Pharetrones and of two species from the Cretaceous strata of Vaches Noires, near Havre, in which the spicular structure of the fibre presents important differences from that of the Warminster specimens.

Verticillites D'Orbignyi, n. sp.

(Pl. X. figs. 1, 2, 7, 8; Pl. XI. figs. 1–24.)

The examples of *Verticillites* which I propose naming *V. D'Orbignyi* are small club-shaped sponges from 16 to 23 millim. in height, growing either singly or in small groups from a common base. Not infrequently new individuals spring from the sides or near the summits of others, as if by a process of budding. In some examples the base is contracted to a minute blunted stem; in others it expands to form a surface of attachment. Above the base is the first chamber, which is small and inconspicuous, and succeeded above by other subspherical chambers, arranged in single series, usually four to six in number. Each chamber is larger than the one beneath; and the summit-chamber is conspicuously the largest. The chambers, excluding the summit, are each from 2 to 4·5 millim. in height and from 4 to 6·5 millim. in width; the summit-chamber is from 6 to 9 millim. in height and from 9 to 14 millim. in width. The roof of each chamber in the series forms the floor of the one above it; and the different chambers are connected together by an interior tube passing through them. I have only been able to examine this tube in a single specimen, in which it appears to be imperforate. The summit of each chamber is depressed, dome-shaped, with a circular aperture in the centre, which in the summit-chamber is 2·25 millim. in width, and is bordered with a slightly elevated collar with smooth even margins. The walls of the sponge are only ·16 millim. in thickness, and appear to be formed of a single thin layer of fibre. The outer surface is smooth, and perforated with numerous minute circular or oval apertures, about ·25 millim. in width and about their own diameters apart. These apertures open directly into the interior chambers.

The fibres forming the wall of the sponge are entirely composed of spicules, apparently disposed in two layers—an outer or dermal layer, and beneath this the inner layer, forming the main portion of the fibre. I have obtained spicules from both these layers and mounted them in Canada balsam. Seen by transmitted light they are translucent, with occasionally a yellowish tint. Their outer surfaces have generally a rough eroded aspect, as if covered with a powdery coating of minute earthy particles, though probably this appearance is really due to a partial decomposition of the spicule itself. Some of the rays of the larger spicules exhibit a smooth surface and even outlines, though in no instance comparable to the exquisite smoothness of the spicules of existing sponges. Under polarized light the fossil spicules occasionally exhibit faint prismatic tints of the same character, but less distinct than those shown by recent calcareous spicules. I have not discovered any traces of an interior canal in these spicules.

The spicules forming the outer layer of the sponge are either three- or four-rayed, and vary considerably in size. Three rays of the spicule are horizontally extended in the same plane, radiating from a common centre; in section each ray is circular, thick-set at the centre, where it connects with the others, and gradually tapering to the extremity, which is bluntly pointed. Two of the three rays of the spicule are equal or very nearly equal in length, such as are termed by Häckel "lateral" or paired-rayed, whilst the opposing ray, the "basal" ray of Häckel, is either longer or shorter than the lateral rays. Where a fourth ray is present (the "apical" ray of Häckel), it springs from the central point of the three rays and at right angles to them. In this species the lateral or paired rays of the relatively large dermal spicules are either straight or nearly so, as in Pl. XI. figs. 3, 4, or possess a slight curve, which may be either towards the basal ray, as in figs. 5–8, or away from it, as in figs. 1, 2. The angle formed by the lateral rays varies from 160° to 180°, whilst that on either side of the basal ray correspondingly varies between 90° and 100°. The paired rays are usually both longer and stouter than the basals. The apical ray, where present, appears to be shorter than any of the facial rays. There are great variations in the dimensions of these surface tri- and quadriradiate spicules. The length of *ray* in the largest which I have been able to measure is ·24 millim. by ·054 millim. in thickness, whilst in a small specimen the ray is only ·05 millim. in length by ·015 millim. in thickness.

The spicules of this surface or dermal layer are disposed with their facial planes parallel with the wall, so that the rays rest on the surface without spreading over the circular apertures. In some portions the basal ray of the triradiates is directed towards the base of the sponge; but in general no regular disposition of the spicules is apparent. The apical ray of the quadriradiate spicules appears to penetrate the wall at right angles to its surface. The majority of the dermal spicules seem to be quadriradiate; but in some no trace of a fourth ray can be detected. The largest of these spicules are disposed on the surface with their rays nearly touching; the smaller forms appear to be disposed beneath and between the rays of the larger.

Beneath this surface-layer of tri- and quadriradiates the wall-fibre of this sponge is composed of spicules of a very different form. These latter are in reality triradiates also, though at first sight scarcely to be recognized as such. They are mostly elongated, curved, filiform bodies, with a small projecting knob in the middle (Pl. XI. figs. 18–23); many are nearly straight or geniculate (figs. 14, 15), also provided with a similar central projection, which represents the basal ray of a triradiate spicule, on either side of which are the lateral or paired rays. The rays are nearly of an even thickness throughout their length; in some they slightly diminish towards the extremities. The minute basal ray is in the same plane with the lateral rays, and, in the case of the curved forms, always springs from the outer or convex side of the curve. From their extreme delicacy it is rare to obtain these filiform spicules entire; the rays are usually fractured, and the broken portions might be mistaken for uniaxal spicules; but I have not detected simple uniaxal spicules anywhere in this sponge. The largest which I have been able to measure is ·3 millim. from end to end, or ·15 millim. of a single lateral ray, whilst the thickness is ·006 millim. The knob or basal ray is only ·009 millim. in length, and is, I believe, complete. The fibre of the sponge is built up of these filiform spicules (figs. 18–23) disposed close together, though not absolutely parallel with each other; for many rest across the others, though generally in the same direction. The curved spicules are mostly disposed round the margins of the canals which penetrate the wall. The geniculate spicules (figs. 14, 15) are rare forms; so also is the spicule represented in fig. 16, which appears in form to be intermediate between the spicules of the dermal layer and those of the interior fibre. The triradiate (fig. 24) with all the rays unequal is also a rare form. I have carefully searched all the fragments of the fibre without discovering other than these filiform spicules in it. The inner or cloacal surface of the fibre, which faces the interior cavity of the sponge, appears to be unprovided with any special layer of spicules similar to those of the dermal surface.

The spicules met with in this sponge are in form so distinctly typical of calcareous sponges, that it would seem hardly necessary, but for the great doubt which has been manifested respecting the affinities of the Pharetrones, to point out in detail their close resemblance to those of existing Calcisponges. We have only to turn to the beautiful figures in Häckel's monograph to find a resemblance in form, and, as regards the dermal spicules, a correspondence in position which conclusively shows a relationship between these fossils and the recent examples of the order. Beginning with the large quadriradiate spicules of the dermal surface with the lateral rays curved away from the basal, as in figs. 1, 2, Pl. XI., we find closely corresponding forms in the dermal spicules of *Leucandra Johnstonii*, Carter, sp., = *Leuconia nivea*, Bowerb., Häckel, Monogr. Bd. ii. p. 216, T. 34. f. 1 *a*. In conjunction with the large quadriradiates in this recent sponge, there are, according to Häckel, numerous triradiates very variable in size and form; the majority are subregular or sagittal, many irregular, and few completely regular (T. 34. f. 1 *a*, *b*). These correspond in form, though larger in size than those which I have represented in figs. 9–13, 16, 17, Pl. XI. In this recent species Häckel states that the three facial rays of the large quadriradiates lie on the dermal surface, while the apical ray bores through the wall into the cloacal cavity, thus corresponding in position to the dermal spicules of the fossil form.

The pickaxe form of dermal spicule with the lateral rays turned towards the basal ray occurs in the surface-layer of *Leucaltis clathria*, Häckel, Monogr. Bd. ii. p. 159, T. 28. f. 36, and *Leucandra cucumis*, Häck. Mon. p. 205, T. 33. f. 1 *f*; but the recent forms are two or three times as large as the fossil. The spicule represented in fig. 4, Pl. XI., with the lateral rays in a straight line, also occurs in the recent *Leucandra stilifera*, O. Schmidt, sp., Häck. Mon. T. 33. f. 4 *d*. Coming now to the smaller spicules, the sagittal triradiates, represented in figs. 14, 15, are similar to the medium small triradiates of the cloacal surface of *Leucaltis solida*, O. Schmidt, sp., Häck. Mon. T. 27. f. 3 *f*; but the basal ray is not so reduced in these as in the fossil forms. In this recent sponge there are also small triradiates similar to those of my figures 9–13, 24, Pl. XI. I have not been able to discover any spicules of recent Calcisponges which closely resemble the slender filiform spicules which mainly compose the fibre in this fossil species, figs. 18–23. The form which approaches the nearest is one figured by Bowerbank from *Leuconia fistulosa*, Mon. Brit. Sp. vol. iii. pl. v. f. 16; but in this the basal ray, though small, is by no means reduced to the insignificant proportions of that of the fossil.

Whilst the various forms of spicules present in this fossil thus closely resemble the spicules in recent Calcisponges, they do not correspond to the spicules of any known siliceous sponge, whether fossil or recent. The skeleton of some siliceous tetractinellid sponges is built up of three- and four-rayed spicules; but in the large majority of these, the rays are equal in length, they radiate from the centre at equal angles, and are but seldom in the same plane, but usually elevated in the form of a three-sided pyramid, with the fourth ray at the apex. No one at all acquainted with sponge-spicules would confound these with the spicules of calcareous sponges.

A dermal surface-layer of large quadriradiate spicules similar to those present in this fossil appears to be a common feature in several existing Calcisponges, amongst others in *Leucaltis clathria*, Häck. Mon. Bd. ii. p. 159, T. 28. f. 3, and *Leucaltis crustacea*, Häck., Mon. Bd. iii. Taf. 28. f. 1; but in no existing sponge is there the same disposition of the spicules of the interior to form anastomosing solid fibres as in this and other allied fossil forms; and this character forms the distinctive feature of the Pharetrones, sharply marking them off from the families of existing Calcisponges.

The main differences between this species and *Verticillites anastomans*, Mantell, sp., 'Wonders of Geology,' p. 636, f. 3, consist in its mode of growth, the chambers being spherical instead of cylindrical, and the upper much larger than those beneath. I am unable to determine if there are any differences in the spicular structure of the two species; for though the examples of *V. anastomans* are very abundant in the Faringdon gravels, in none are dermal spicules visible. D'Orbigny has mentioned a species of *Verticillites* under the name of *V. incrassata*, Prodr. de Pal. vol. ii. p. 186; but as the only reference to it, contained in the following paragraph, "Espèce dont les tiges grossissent de la base au sommet au lieu d'être cylindriques," is obviously insufficient for satisfactory recognition, I have preferred to give a new designation to this species.

Horizon and Locality. Upper Greensand, Warminster, Wiltshire.

Coll. British Museum of Natural History (Cunnington coll.); Museum of Practical Geology, Jermyn Street.

Corynella rugosa, n. sp. (Pl. X. fig. 4; Pl. XI. fig. 25.)

The examples of this species are all simple, and in form cylindrical, straight or curved. The base is contracted to a minute blunted stem; and the summit is truncate. The outer surface has concentric ridges, which are either continuous or broken up into tubercular elevations. An average specimen is 48 millim. in height and 18 millim. in thickness. The cloaca is in the form of a cylindrical tube; the aperture at the summit is 4 millim. in width. The walls vary in thickness between 4 and 7 millim.

The sponge-walls are formed of anastomosing fibres, of the same character as those of *V. D'Orbignyi*; but instead of a single layer one sixth of a millim. in thickness, there is a continuous network 5 to 7 millim. in thickness, extending from the exterior to the surface of the central cloacal tube. The exterior is smooth, and exhibits closely arranged, approximately circular apertures, which are in fact merely the interspaces between the network of the fibres. The examples do not show the interior surface of the cloaca.

A dermal layer of relatively large spicules can be detected here and there on the surface; but I have not been able to obtain these detached; so far, however, as they can be observed by the aid of a simple lens, they appear to correspond in form, size, and position with the quadriradiate spicules of the exterior of *V. D'Orbignyi*. I have succeeded, however, in obtaining spicules of the interior fibre free from the matrix, and find them similar in all essential features to the filiform spicules of the preceding species. In some the basal ray is slightly longer and terminates acutely. The arrangement of the spicules in the fibre is also precisely similar to that already described in *V. D'Orbignyi*. This similarity in the spicular structure is of great interest when one considers the diversity in the form, size, and thickness of the wall in these two sponges.

Horizon and Locality. Upper Greensand, Warminster, Wiltshire.

Collection. British Museum of Natural History (Cunnington coll.).

Corynella socialis, n. sp. (Pl. X. fig. 3.)

Sponge compound, consisting of three or more individuals springing from a common cylindrical stem, or else growing by lateral buds. The base either widely expanded or contracted to a blunted point. The summits flat, wide, and obliquely truncate. The outer surface uneven, with short blunted projections. The typical example is 49 millim. in height and 43 millim. in its greatest width. The individual sponges are from 17 to 21 millim. in thickness. The walls vary from 5 to 10 millim. in thickness; and the aperture of the cloacal tube is 5 millim. in diameter.

The outer surface exhibits apertures of irregular form, bounded by the interlacing fibres. In one small part of the surface, spicules, apparently quadriradiate, could be detected. The fibre in one specimen was sufficiently firm to allow a thin microscopic section to be prepared from it. Examined by transmitted light the fibre presented the appearance of well-defined anastomosing bands from ·12 to ·17 millim. in width, of a dark tint, in which are seen numerous delicate, closely arranged, and for the most part parallel thread-like bodies, distinguished by their lighter outlines. These spicules appear, at first sight, to be simple uniaxal forms; but on close inspection, in places where they are less closely packed together, one or two can be seen to be geniculated and to possess a minute projection in the centre, representing the atrophied basal ray of triaxal spicules, similar to the spicules of the fibre of the preceding species. The difficulty of observing the minute basal ray of these spicules in thin sections might easily give rise to error respecting the character of the spicules, as they would be mistaken for uniaxal forms.

In external form this species is allied to *Corynella* (*Distheles*) *excavata*, Roemer (Pal. Bd. xiii. T. 1. f. 19), and *C.* (*Distheles*) *depressa* (Fromentel, Introd. T. ii. f. 7); but its walls are considerably thicker, and both the individuals and the compound form are notably larger.

Horizon and Locality. Upper Greensand, Warminster, Wiltshire.

Collection. British Natural-History Museum (Baker coll.).

Sestrostomella rugosa, n. sp.
(Pl. X. fig. 6; Pl. XII. figs. 1–15.)

Sponge compound, growing in upright bushy masses, consisting of several individuals, from conical to cylindrical in form; united at their bases, and occasionally laterally, but with free summits. The typical specimen is 68 millim. in height, and 76 millim. in greatest breadth. The individuals are about 12 millim. in thickness. The lower portion of the specimen figured appears to have been enveloped in a compact rugose external membrane. The summits of the individual sponges are either rounded or truncate. The external surface, save in the lower portion of the specimen, where the compact membrane is present, is extremely rough, and exhibits an irregular open network of coarse fibres. From the summits of some of the individual sponges, well-defined deep open canals extend downwards. The cloacal aperture, where present, is about 2 millim. in width; but in some individuals it seems absent, and the summit only shows the interstitial apertures between the fibres; but the open canals are present, just the same as in the individuals with a distinct cloacal aperture.

I have not detected any dermal spicules in this species, and, considering the rough character of the exterior, one could hardly expect to meet with them. But though unsuitable in this respect, the condition of the sponge is very favourable for the preparation of thin sections. In a transverse section, taken from the basal portion of a specimen, examined by transmitted light, the fibres appear as bright translucent bands from ·2 to ·41 millim. wide, in a brownish calcareous matrix. The outlines of the spicules appear as very fine lines. Where the plane of the section intersects the fibre in the direction of its length, it appears as a broad band with well-defined margins; when the fibre is cut transversely, the section is circular. The fibre exhibits an altogether different character in the form and arrangement of the component spicules from that which prevails in the examples of *Verticillites* and *Corynella*, already described. Instead of a regular disposition of parallel filiform spicules, nearly uniform in thickness and length, the fibre of this species is composed of spicules very variable in form, and ranging in size between very large and very small forms. A fragment of the fibre and different forms of the spicules are represented in Pl. XII. figs. 1–15. As these figures are drawn with the camera lucida on the same scale of 200 diameters, an idea may readily be formed of the variation in size of these spicules. The central portion of the fibre generally appears to be occupied by a large tri- or quadriradiate spicule, one ray of which extends along the central axis of the fibre, as shown in fig. 1 *a* and in section fig. 2 *a*. Sometimes but a single ray of this central spicule is visible in the plane of the section; in other instances portions of three rays are visible, as in fig. 3. The largest ray of these central spicules which I have met with is ·5 millim. in length and ·05 millim. in thickness. Beyond this centrally-placed large spicule the remaining portion of the fibre appears to be composed of several different forms of triradiate spicules, whose rays are so compactly and intricately interlaced together that it is extremely difficult to ascertain their complete forms with any degree of precision. Of those recognizable, some appear to be sagittal tri- and quadriradiates, figs. 1 *b*, 5, 9–11, with rays from ·03 to ·06 millim. in length; others pickaxe in form (fig. 8), or rudely fork-shaped with wide irregularly curved prongs (fig. 6); whilst others are regularly fork-shaped (figs. 12–15), with short, slightly-curved lateral rays and a slender, straight, tapering basal ray, varying in total length between ·07 and ·19 millim. These spicules appear to be distributed in the fibre without any definite order; in a few instances, however, I have noticed the small regular fork-shaped spicules, with their prongs or lateral rays directed towards the margin of the fibre and the basal ray penetrating inwards; but this disposition does not appear to be constant.

It is only by careful search that the small spicules just mentioned can be singled out in the confusedly mingled mass of spicular forms present in the fibre; the general appearance of the fibre is that of numerous very fine, sinuous, interrupted lines, which run parallel with the direction of the fibre, and are closest arranged near the margins. I have been unable to determine satisfactorily the character of these minute wavy lines. In part they appear to be formed by the closely interlacing rays of irregularly fork-shaped spicules similar to that represented in fig. 6; but they may also indicate the bisected outlines of very minute spicules which are so interwoven and dovetailed into each other that the separate forms cannot be distinguished. In the recent sponges *Leucandra Johnstonii*, Carter, sp. (Ann. & Mag. Nat. Hist. 1871, vol. viii. p. 3, t. 1. figs. 5–12), and *Leucandra stilifera*, O. Schmidt, sp. (Atlan. Spong. p. 73, t. 2. fig. 24), and some other forms as well, the skeleton is in part composed of relatively very large quadriradiate and very minute uniaxal and quadriradiate spicules. Häckel states (Mon. Bd. ii. p. 225) that in the last-named species, *L. stilifera*, the minute uniaxal spicules are mixed up together in masses which may be compared to stucco or mortar, which covers the smooth dermal and gastral surfaces, and envelops and connects together the large and colossal quadriradiates which form the scaffolding of the skeleton. It seems to me probable that in this fossil species the large quadriradiate spicules of the centre of the fibre are similarly enveloped by minute spicules, and that the minute wavy lines seen in the thin microscopic section may be the outlines of a compact felted mass of these diminutive bodies.

The tri- and quadriradiates of this fossil are precisely similar in form to spicules met with in several species of Häckel's recent genus *Leucandra*; but in respect of their dimensions, the largest fall short of the size of some of the spicules of the recent sponges. The pickaxe spicule (fig. 8) and fork-shaped spicules (figs. 6, 12–15) are more specialized and restricted forms, consequently of greater value for comparison; for if these very peculiar types occur in recent Calcisponges, but little doubt can be entertained of the calcareous origin of the fossil sponges. It is therefore satisfactory to find that spicules of similar form are present in the skeleton of two recent species of calcareous sponges, *Leucetta pandora*, Häck. (Mon. Bd. ii. p. 127, Taf. xxii. f. 3 *a–c*, Taf. xxiii.), and *Leucortis pulvinar* (Häck. p. 166). Similar spicules were first figured by Bowerbank (Mon. Brit. Spong. vol. i. p. 268, pl. x. f. 237) from a calcareous sponge from Freemantle, Australia. On these, Gray founded a new genus and species, *Lelapia australis* (Proc. Zool. Soc. 1867, p. 557). It is interesting to note that the two species with this spicule described by Häckel are also found on the south coast of Australia and in the Indian Ocean. If we turn to Häckel's figures of the different forms of spicules of *Leucetta pandora*, on Taf. xxiii., which are magnified to the same scale of 200 diameters as those on my Plate XII. we find that the forms which he terms "anchor-shaped triradiates," with recurved sagittate rays (*i*), correspond with the pickaxe spicule of my fig. 8; the fork-shaped spicules with open prongs (fig. 6) resemble those which Häckel terms completely irregular triradiates (*p*); whilst the small fork-shaped fossil spicules (figs. 13–15) may be compared with those of Häckel's fig. *h*; the fossil spicules, however, are much smaller and slenderer forms than the recent, and the basal ray gradually tapers instead of being swollen at its extremity. The variability of the spicules in this fossil seems to be almost as great as in the recent sponge, of which Häckel states that its skeleton may be considered a complete armoury for all possible forms of triradiate spicules.

Judging from the form and canal-system this fossil species appears to belong to Zittel's genus *Sestrostomella*. Up to the present, however, the spicular characters of the type species of this genus have not been ascertained; and until these are known the generic position of this species must be regarded as merely provisional.

Horizon and Locality. Cretaceous, Vaches Noires, near Havre.

Collection. British Natural-History Museum.

Sestrostomella clavata, n. sp.
(Pl. X. fig. 5; Pl. XII. figs. 16–25.)

Sponge compound, depressed, spherical in outline, consisting of numerous cylindrical individuals, mostly free at their summits, but partially united laterally, which grow from a central mass. There are no signs of any stem or expanded surface of attachment; but on the underside there are two smooth small patches on which the sponge seems to have rested during its growth. The individuals are from 8 to 10 millim. in diameter, with rounded summits. The cloacal aperture is about 2·5 millim. in width; in some examples it appears to be replaced by a few oscules or canal-openings. Straight open canals extend from the summit down the sides of some individuals. The outer surface exhibits only the irregular interspaces between the fibres.

A thin transverse section presents under the microscope substantially the same spicular structures of the fibre as in the preceding species, and therefore it will not be necessary to repeat the description of them in detail. Some representations of the spicules of the fibre are given on Pl. XII. figs. 16–24. In fig. 16 are represented portions of the sagittal and basal rays, and the truncated base of the apical ray, of a large quadriradiate spicule. The lateral rays of this spicule appear to have been curved in a similar manner to those of a large triradiate in *Leucetta pandora*, Häck. (Mon. Taf. xxiii. f. *m*, *e*). Portions of smaller tri- and quadriradiates are shown in figs. 17, 18. The fork-shaped spicules (figs. 20, 22–24) closely resemble those of *S. rugosa*. There is also a small irregular triradiate (fig. 21) which is precisely similar to one figured by Häckel in *L. pandora*.

In addition, however, to this spicular structure of the fibre, the type specimen of this sponge exhibits spicules on a small smooth oblong space on the under surface, which I have already mentioned as indicating the part on which the sponge rested during its growth. This spot, 10 millim. long, by 5 wide, is smooth and non-perforate, and is thickly covered by a layer of triradiate spicules, irregularly disposed, with the rays crossing each other (fig. 25). These spicules are sufficiently large to be seen with a simple lens; they vary in size; a fairly large specimen has the rays ·2 millim. long. It is very probable these spicules possess an apical ray penetrating into the interior and are thus really quadriradiates; but I am unable to determine this point. In form they are either sagittate or subregular, *i. e.* having the arms nearly of an equal length and the angles subequal. These spicules, thus apparently restricted to this small part of the exterior surface, closely correspond to the dermal spicules which in *Verticillites* and *Corynella* form a layer over the entire outer surface of the sponge. Notwithstanding the similarity in the spicular structure of the fibre to *S. rugosa*, the form and proportions of the mass and of the component individuals differ sufficiently, in my opinion, to permit this form to be regarded as a distinct species.

Horizon and Locality. Cretaceous, Vaches Noires, near Havre.

Collection. British Natural-History Museum.

From the close similarity which has been shown to exist between the minute spicular characters of the five species above described and those of existing Calcisponges, it seems to me that the originally calcareous composition of the fossil forms can no longer be disputed, and that Prof. Zittel was fully justified in placing together as a distinct family of Calcisponges the numerous sponges with structures similar to the above species.

An examination of some of the calcareous sponges from Farringdon and Upware convinces me that they possess essentially similar minute structures to the sponges from Warminster and Vaches Noires, though, as a rule, their condition of preservation is unfavourable, and in no instance have dermal surface-spicules been detected; but thin sections of the fibres display similar features. For example, *Corynella* (*Scyphia*) *foraminosa*, Goldf., sp. (Petref. p. 86, t. 21. f. 4), from Farringdon, has the fibre made up of minute filiform spicules, apparently similar to those of *C. rugosa*. The fibre also of the common *Pharetrospongia* (*Manon*) *farringdonensis*, Sharpe, sp. (Quart. Journ. Geol. Soc. vol. x. p. 196, t. 5. figs. 5, 6), is similarly of filiform spicules; but whether these are really uniaxal or triradiates with the minute basal ray like those of *Corynella rugosa*, I have not yet been able to determine. The fibre of *Elasmostoma* (*Manon*) *macropora*, Sharpe (Quart. Journ. Gol. Soc. vol. x. p. 195, t. 5. figs. 3, 4), has a spicular structure of tri- and quadriradiates of the same character and arrangement as in *Sestrostomella rugosa*. Prof. Sollas has made this form the type of a new family and genus of *siliceous* sponges (Ann. & Mag. Nat. Hist. 1878, vol. ii. p. 336, fig. 1), on the supposed resemblance of the spicules to those of siliceous monactinellid and tetractinellid sponges, without apparently taking into account, amongst other things, the very great difference of size between the calcareous and siliceous forms, which of itself is sufficient to throw great doubt on their probable affinities. I have not been able to obtain a microscopic section of *Verticillites anastomans*, Mantell, sp. 'Medals of Creation,' vol. i. p. 227, fig. 4), but entertain no doubt that its minute structure will be found to correspond with the closely allied *V. D'Orbignyi*.

Not only in Cretaceous Calcisponges, but also in Jurassic examples, I am able to affirm the presence of a dermal layer of quadriradiate (?) spicules similar to those of the species above described. Thus in *Eudea perforata*, Quenst., sp. (Der Jura, p. 698, t. 84. figs. 26, 27), from the Upper Jura of Nattheim, the summit of the sponge has a layer of these spicules, though they are not to be detected in the compact membrane ("Dermalschicht" of Zittel) which invests the sides of this species; they are also present on the summit of *Eusiphonella Bronni*, Goldf. (Petref. p. 91, t. 33. fig. 9), from the same locality; and it seems very probable that the majority of the Pharetrones possessed a similar dermal layer, which, on account of the minute size of the spicules and the unfavourable condition of preservation, has not been hitherto noticed.

EXPLANATION OF THE PLATES.

Plate X.

Fig. 1. *Verticillites D'Orbignyi*, n. sp., natural size.
Fig. 2. The same, natural size.
Fig. 3. *Corynella socialis*, n. sp., natural size.
Fig. 4. *Corynella rugosa*, n. sp., natural size.
Fig. 4*a*. The same, showing the summit, with the cloacal aperture.
Fig. 5. *Sestrostomella clavata*, n. sp., natural size.
Fig. 6. *Sestrostomella rugosa*, n. sp., natural size.
Fig. 7. Fragment of the outer surface of *Verticillites D'Orbignyi*, showing the apertures in the wall, and the disposition of the large dermal spicules. × 56.
Fig. 8. Fragment of the interior surface of the wall of *Verticillites d'Orbignyi*, showing the arrangement of the minute triradiate spicules composing the fibre. × 56.

Plate XI.

(Figs. 1–24. Detached spicules of *Verticillites D'Orbignyi.*)

Fig. 1. Dermal spicule. Sagittal quadriradiate, with the lateral or paired rays curved away from the basal ray.
Fig. 2. The same. The lateral rays of this specimen are unequal in length, probably owing to the erosion of the shorter ray by fossilization.
Fig. 3. Dermal spicule. Sagittal quadriradiate, with straight lateral rays.
Fig. 4. Dermal spicule. Sagittal quadriradiate, with the lateral rays straight and in a straight line with each other.
Fig. 5. Dermal spicule. Sagittal quadriradiate, with the lateral rays curved towards the basal ray.
Fig. 6. The same. The basal ray more elongated than in the preceding.
Fig. 7. The same. Quadriradiate, with the three facial rays nearly equal in length; the lateral rays are slightly curved towards the basal ray.
Fig. 8. The same. Sagittal quadriradiate, showing the apical ray.
Figs. 9–13. Small forms of dermal spicules; all triradiates, with the rays unequal in length.
Fig. 14. Spicule of the fibre. Sagittal triradiate, with straight lateral rays and diminutive basal ray. This form most frequently occurs on the interior surface of the sponge-wall.
Fig. 15. The same. Triradiate, with unequal lateral rays, and the basal rays reduced to a small knob-like projection.
Figs. 16, 17. Dermal spicules. Sagittal triradiates, showing transitional forms between the dermal spicules and those of the fibre.
Figs. 18–23. Spicules of the fibre. Sagittal triradiates of various dimensions; the lateral rays mostly curved, so as to conform to the curvature of the fibre; the basal ray reduced to a diminutive knob.
Fig. 24. Dermal spicule. Triradiate with all the rays unequal.

Fig. 25. *Corynella rugosa.* Spicule of the fibre. Sagittal triradiate, with straight lateral rays.

All the above figures are drawn by means of the camera lucida, and magnified to the same scale of 200 diameters.

PLATE XII.

Fig. 1. Longitudinal microscopical section of a portion of the fibre of *Sestrostomella rugosa*, as seen by transmitted light, showing one ray of a relatively large tri- or quadriradiate spicule in the centre (*a*), and the bisected outlines of sagittal and irregular triradiate spicules (*b*), which are confusedly intermingled together to form the fibre.

Fig. 2. Transverse section of the same, showing a cross section of one ray of a large central spicule (*a*), and the cut edges of the smaller triradiates surrounding it. The finer lines near the margin of the fibre in this and the preceding figure are probably outlines of minute spicules, so compactly wedged together in the fibre that the individual forms cannot be distinguished.

Fig. 3. *Sestrostomella rugosa.* Fragment of a large triradiate spicule, showing portions of the three rays, from the interior of the fibre, as seen in a microscopic section.

Fig. 4. The same. Fragment of triradiate spicule with unequal arms.

Fig. 5. The same. Fragment of quadriradiate spicule.

Fig. 6. The same. Triradiate (fork-shaped) spicule with irregular and unequal arms.

Fig. 7. The same. Irregular quadriradiate spicule.

Fig. 8. The same. Sagittal triradiate (pickaxe) spicule, with the lateral rays (imperfect) curved towards the basal ray.

Figs. 9–11. The same. Triradiate spicules, the rays incomplete.

Figs. 12–15. The same. Triradiate (fork-shaped) spicules from the fibre, showing the elongate basal ray and the lateral rays, often slightly unequal in length, and curved backwards, so as to become nearly parallel with each other.

Fig. 16. *Sestrostomella clavata.* Portion of large quadriradiate spicule, showing the imperfect sinuous facial rays and the truncated base of the apical ray, from a microscopic section of the fibre. The irregular lines within the spicule are apparently fractures in its substance.

Fig. 17. The same. Quadriradiate spicule (imperfect) similar to but smaller than the preceding.

Fig. 18. The same. Triradiate spicule.

Fig. 19. The same. Portion of a minute quadriradiate spicule.

Figs. 20, 21. The same. Fragments of irregular triradiate (fork-shaped) spicules.

Figs. 22–24. The same. Triradiate (fork-shaped) spicules, showing slight variations in size and form.

Fig. 25. The same. Triradiate (?) spicules, subregular in form, from a small smooth portion of the exterior surface of the sponge, probably the part from which the growth of the sponge commenced. × 150.

With the exception of fig. 25, all the above are drawn from microscopic sections by means of the camera lucida, and magnified to the same scale of 200 diameters.